Synopsis for Ph.D. Programme

Title of the Research:

Studies on Bioconvection of Nanofluids over a Stretching Sheet

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Flow of Newtonian and non-Newtonian fluids over a stretching sheet is one of the most important topics in fluid dynamics to the researchers due to its various application in industries and manufacturing process such as polymer devolatisation, plastic foam processing, bubbles absorption, fermentation etc. There are different kinds of non-Newtonian fluids with numerous characteristic in nature such as Micro-polar fluid, Powell-Eyring fluid, Power-law fluid etc. Researchers are more interested to study heat and mass transfer in different types of non-Newtonian fluid. There exist many previously published paper considering Powell-Eyring fluid, Micro-polar fluid, Power-law fluid etc. in the presence of magnetic field, linear/nonlinear thermal radiation, chemical reaction, viscous dissipation, uniform heat source/sink etc. Akbar et al. (2015) examined the influence of magnetohydrodynamics on two-dimensional flow of Eyring-Powell fluid model towards a stretching sheet. They solved the governing equations by implicit finite difference method. Hayat et al. (2015) investigated effects of convective heat and mass transfer in flow of Powell-Eyring fluid past an exponentially stretching sheet. In this paper mathematical formulation and result analysis have been carried out in the presence of thermal radiation and Soret, Dufour effects. They solved the governing partial differential equations by Homotopy analysis method (HAM). Hayat et al. (2017) examined the magnetohydrodynamic boundary layer flow of Powell-Eyring nanofluid over a non linear stretching sheet with variable thickness. In this study the flow analysis has been carried out by considering zero nanoparticle mass flux and the governing equations are solved by series solution. Mishra et al. (2016) studied the free convection effects of a micro-polar fluid along a stretching sheet embedded in a porous medium in the presence of a volumetric non-uniform heat source. Pal et al. (2016) analyzed the problem of steady, magnetohydrodynamic laminar double-diffusive convection heat and mass transfer of a micro-polar fluid over a vertical permeable semi-infinite plate embedded in a uniform porous medium in the presence of non-linear thermal radiation. In this article, it is found that increase in the inverse Darcy number results in decrease in the velocity and micro-rotation distributions whereas reverse effects are observed on the temperature and concentration distributions.

The study of nanofluid flow over a stretching sheet is a special interest to the researchers and scientists due to its practical applications in manufacturing processes in industry such as the cooling of the metallic plate, nuclear reactor, extrusion of polymers etc. The study of magnetohydrodynamic (MHD) convective heat and mass transfer near a stagnation-point flow over stretching/shrinking sheet of nanofluids is presented by Pal and Mandal (2017). In this paper they considered the effects of thermal radiation, Ohmic heating, viscous dissipation and sink parameter/sink on the flow.

The study of bioconvection of nanofluid flow in the presence of motile gyrotactic microorganisms is an important topic to the researchers due to large amount of applications in biomedical and in advanced nanomechanical bioconvection energy conversion devices, bio-nano-coolant systems etc. Bioconvection occurs due to the density gradient of bottom heavy motile microorganisms such as algae, bacteria. These microorganisms are bottom heavy because their center of mass is located behind the center of buoyancy. These microorganisms are self-propelled and the collective swimming of motile microorganisms in the upward direction increase the density of the base fluid water in the upper region. Bioconvection has many applications in bio-microsystems, such as enzyme biosensors and biotechnology due to the mass transport enhancement and mixing,

which are important issues in many micro-systems. Motile microorganisms are added with dilute suspension of nanoparticles to improve the rate of mass transfer, microscale mixing especially in microvolumes and improve the stability of nanofluid in the flow. The presence of magnetic field has a significant effects on the behaviour of the microorganisms.

Recently, several researchers have focused their attention to the problem of MHD bioconvection flow of gyrotactic microorganisms. Kuznetsov and Bubnovich (2012) discussed the simultaneous effects of gyrotactic and Oxytactic microorganisms on nanofluid bio-thermal convection in porous medium. MHD laminar boundary layer flow with heat and mass transfer of an electrically conducting water-based nanofluid containing gyrotactic microorganisms along a convectively heated stretching sheet is investigated numerically by Khan and Makinde (2014). Shaw et al. (2014) investigated Soret effects on bioconvection in a porous medium with a nanofluid containing gyrotactic microorganisms. Mutuku and Makinde (2014) studied the bioconvection induced by the hydromagnetic flow of a novel type of a water based nanofluid containing nanoparticles and motile microorganisms past a permeable vertical moving surface. Khan et al. (2014) studied the combined effects of Navier slip and magnetic field on boundary layer flow with heat and mass transfer of a water-based nanofluid containing gyrotactic microorganisms over a vertical plate. Das et al. (2015) discussed the hydromagnetic bioconvection of gyrotactic microorganisms past a permeable vertical plate embedded in a porous medium filled with a water-based nanofluid. Magnetohydrodynamic (MHD) bioconvection of an incompressible electrically conducting nanofluid near a vertical wavy surface saturated porous medium containing both nanoparticle and gyrotactic microorganisms investigated by Ahmed and Mahdy (2016). Hady et al. (2016) presented a numerical study of the problem of unsteady thermo bioconvection boundary layer flow of a nanofluid containing gyrotactic microorganisms along a stretching sheet under the influence of magnetic field and viscous dissipation. Khan et al.(2016) investigated the influence of viscous dissipation and joule heating on MHD bioconvection flow over a porous wedge in the presence of nanofluid and gyrotactic microorganisms. There also exist bioconvection flow of Power-law nanofluids. Beg et al. (2015) studied the bioconvection flow of Power-law nanofluids over a horizontal flat plate in a porous medium saturated with gyrotactic microorganisms. They found that their results are relevant to improving performance of microbial fuel cells.

The effects of linear and non-linear thermal radiation plays an important role in bioconvection flow by controlling the heat and mass transfer in cooling process. Recently, several researchers have focused their attention to study the effect of thermal radiation on bioconvection flow of gyrotactic microorganisms over a stretching sheet. Makinde and Animasaun (2016) discussed the effects of magnetic field, nonlinear thermal radiation and homogeneous-heterogeneous quartic autocatalysis chemical reaction on an electrically conducting alumina-water nanofluid containing gyrotactic microorganisms over an upper horizontal surface of a paraboloid of revolution. Acharya et al. (2016) examined the effects of solar radiation on hydromagnetic bioconvection of water-based nanofluid flow in presence of gyrotactic microorganisms past a permeable surface under the effect of surface slip condition. Recently, Ramzan et al.(2017) analyzed the biconveciton nanofluid with gyrotactic microorganism in the presence of non-linear thermal radiation and convective heat and mass boundary conditions.

Thus, motivated by above literature, we are interested to study the bioconvection in the presence of motile gyrotactic microrganisms over a stretching sheet for both Newtonian and non-Newtonian nanofluid fluid such as Micro-polar nanofluid, Powell-Eyring nanofluid, Power-law nanofluid, in the presence of magnetic field, linear/nonlinear thermal radiation, chemical reaction, viscous/ohmic dissipation etc. We are also interested to study the entropy generation analysis for few of above stated bioconvection problems by considering various physical phenomena. Flow would be in-

compressible, laminar, steady/unsteady, viscous. The boundary conditions would be convective, no-slip, Navier slip etc. The nonlinear governing partial differential equations would be solved by Runge-Kutta-Felhberg Method along with shooting technique by transforming those equations to nonlinear ordinary differential equations by similarty transformation. So the proposed thesis work will be covering the following areas:

1. The effect of magnetic field on nanofluid bioconvection over an exponentially stretching sheet in the presence of gyrotactic microorganisms and thermal radiation;

2. Influence of chemical reaction and nonlinear thermal radiation on hydromagnetic bioconvection of nanofluid containing gyrotactic microorganisms over an exponentially stretching sheet;

3. Hydromagnetic bioconvection in a suspension of chemically reactive gyrotactic microorganisms in a Powell Eyring nanofluid over a convictively heated stretching in the presence of nonlinear thermal radiation;

4. Magnetohydrodynamic unsteady bioconvection in boundary layer flow of Powell Eyring nanofluid in the presence of gyrotactic microorganisms over a nonlinear stretching sheet with non uniform heat source/sink;

5. MHD bioconvection in micro-polar nanofluid containing gyrotactic microorganisms over a stretching sheet in porous medium with Navier slip condition;

6. Stagnation point flow of power-law nanofluid containing gyrotactic microorganisms over a stretching sheet with viscous dissipation and magnetic field;

7. Bioconvection of Magnetohydrodynamic Power-law nanofluid in porous media containing gyrotactic microorganisms over a nonlinear stretching with viscous dissipation and chemical reaction over a wedge surface;

8. Numerical Simulation of entropy generation of magneto-thermo heat transfer over a inclined stretching sheet in the presence of non-linear heat generation and chemical reaction.

   The above proposed work would be interesting and important in the field of industries and manufacturing processes. We hope the result would be very useful and taking the computed results one can improve the manufacturing processes in industries.

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